International Basic and Applied Research Journal

Journal homepage: https://sites.google.com/site/ijbarmeplrf/

Research Article (Subject – Geophysics, Geochemistry)

# Magnetic, Radiometric and Geochemical Survey of Quarry Sites in Ondo State, Southwestern, Nigeria

Cyril C. Okpoli* and Adedibu Sunny Akingboye
Department of Earth Sciences, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria.
*cyril.okpoli@aaua.edu.ng

Received: 07 June 2016, Revised Received: 08 July 2016, Accepted: 10 July 2016

## Abstract

Integrated high resolution ground magnetic, radiometric and geochemical investigation were carried out in three Quarries in Ondo State with the aim of characterizing the magnetic intensities, radioactivity, delineating subsurface structures, anomalous zones with depth to magnetic sources and also to determine the geoenvironmental hazard potential of concentrations of various elements due to quarrying activities. Proton Magnetometer was used for Magnetic survey. Gamma ray spectrometer was used for radiometric surveys. The geophysical data were processed using the Geosoft® Oasis Montaj and soil geochemistry analyses done with X-Ray fluorescence (XRF). Results obtained from magnetic images showed lows and highs from evaluation of the individual maps and revealed amplitude variation between -3326.79nT and 1284.61nT, indicating lineament structures with infilled geologic materials (lows) and closeness/outcropping basement (highs). Euler Deconvolution and its 3D view sequentially reveal the orientation of the structures with their depths and the alignment of anomalous zones to the base and basement outcropping at the surface. RAPS showed different range of depth estimates between 100m to 800m indicating the total depth estimate to the top of geologic sources that produced the observed anomalies. The Radio-elements have mean concentrations of 2.85 %, 4.8 ppm and 16.3 ppm for K, U and Th respectively. The relatively low and high values of magnetic intensities recorded in the study area may be attributed to the perceived variations in the magnetic properties that correlate to the acidic intrusive and metamorphosed igneous rocks in the study areas. The results obtained from the XRF for geochemical assessment revealed the impact of the quarrying activities and showed the abundance of the major elements to be in the order of Fe>Ti>K>Ca, heavy metals: Zn>Cu>Pb>As, and trace elements: Mo>Mn>Zr>V>Ce>Cr respectively. The analyzed soil samples from the study area were below the tolerance level when compared with international standard and the area is considered safe to humans for agricultural practices, drinking and for other purposes.

**Keywords:** Magnetics Intensity, Radio-elements, Geochemistry, Quarry, Metals, Elements.

## Introduction

Humans are always exposed to background radiation that comes from both natural and human-made sources. The knowledge of radionuclide distribution levels in the environment is important in assessing the effects of radiation exposure due to natural and human-made sources. Natural radioactivity concentrations depend mainly on geological and geographical conditions and appear at different levels in soils of different geological regions (UNSCEAR, 2000).Soil radionuclide activity concentration is one of the main determinants of the natural background radiation. When rocks are disintegrated through natural process, radionuclides are carried to soil by rain and water flows (Taskin, et al., 2009). In addition to the natural sources, soil radioactivity is also affected by human-made activities.

Consequently, cultivation of crops for human or livestock consumption on contaminated soil can potentially lead to the intake and accumulation of trace metals in the edible plant parts with a resulting risk to human and animal health (Esshaimi et al., 2012). Evidence has shown that that heavy metal pollution of mined areas caused health damage to the local inhabitants (Kachenko and Singh, 2006). Serious systematic health problems can develop as a result of excessive dietary accumulation of heavy metals such as Pb in the human body (Oliver, 1997). Although Zn and Cu are essential elements, their excessive concentration in food and feed plants are of great concern because of their toxicity to humans and animals. Lead and Zinc are considered potential carcinogens and are associated with etiology of a number of diseases especially cardiovascular, kidney, nervous system as well as bone diseases (Jarup, 2003).

Man's quest for growth and development has really affected human environment at large due to quarrying activities to exploit the minerals in past and present. The issues of study include: damage to landscapes; leading to increase in fracturing density of the basement that could result into subsidence/collapse of buildings, smoke, noise, dust, damage to caves, loss of land; deterioration in water quality and the abandon mine created as a result of the above activities. Abandon mines are sites where advance exploration, mining or mine production are implemented or completed but ceased without rehabilitation. It is a situation whereby the land is left un-vegetated and exposed, while waste materials were left in piles or haphazardly dumped into mine cavities or pits and often in locations of natural drainage such that surface water run-off and infiltration have caused natural leaching from waste rock piles.

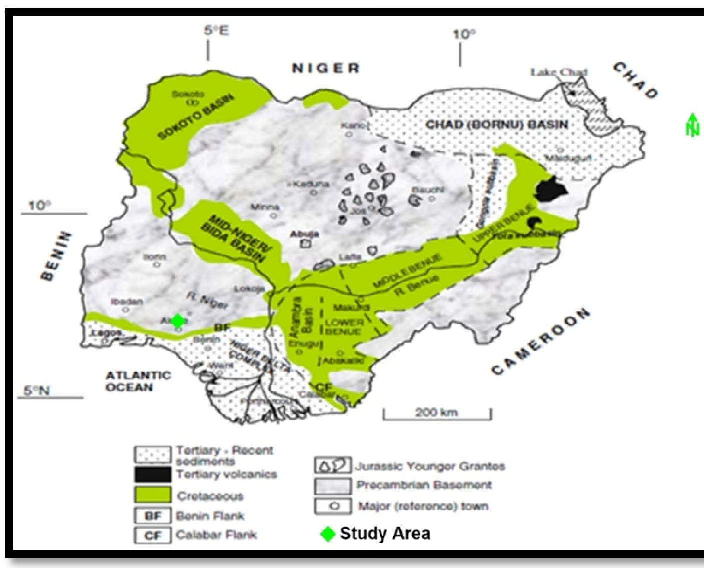



**Fig. 1. Generalized Geological map of Nigeria showing the Study area (Adapted from Obaje. 2004).**

Waste rock/gangue geochemistry varies widely from mine to mine and may vary significantly at individual mines over time as differing lithologic strata are exposed and geochemical processes alter characteristics of the work (Adabanija and Oladunjoye, 2014).

Radiometric survey measures the spatial distribution of three radioactive-elements. That is Uranium (U-238), Thorium (Th-232) and Potassium (K-40) in the top 30-45cm of the earth's crust (Gregory & Horwood, 1961). The abundances of K, Th and U are measured by detecting the gamma-rays produced during the natural radioactive decay of these elements and the abundance of these radioactive elements changes across the earth's surface with variations in rock and soil type.

Ground based magnetic method is used for detailed mapping in order to comprehend the subsurface geology of an area. It has been used extensively in basement mapping (Folami, 1992). The technique requires measurement of the amplitude of magnetic components at discrete points along traverses distributed regularly throughout the survey area of interest. In ground magnetic study, three components are measured which are horizontal, vertical and total components. The vertical components are mostly used in the past studies to delineate faults, fractures, depth to magnetic basement and other structures (Nettleton, 1976).

The aim of this work is to characterize the magnetic intensities, delineating subsurface structures, and anomalous zones with depth to magnetic sources. The radio-elements and artificially (blasting and mechanical devices) that could act as seepage for leachates from contaminated soil. Geochemical approach will assess the geo-environmental hazard potential of concentrations of both heavy metals and trace elements in the soil samples due to quarrying activities.

## Geologic Setting of the Study Area

The study area (Elegbeka, Ayegunle and Supare) lies within Latitude **$07^0$00'N - $07^0$30'N** and Longitude **$05^0$30'E - $05^0$60'E** (Figs. 1 and 2) within the basement complex of Nigeria and underlain by Southwestern Nigeria's Precambrian basement complex rocks. The Basement Complex rocks of Nigeria form part of the African crystalline shield which occurs within the Pan African mobile belt that lies between the West African and Congo Cratons and South of the Tuareg Shield which were affected by the Pan-African orogeny (Oyawoye, 1972).

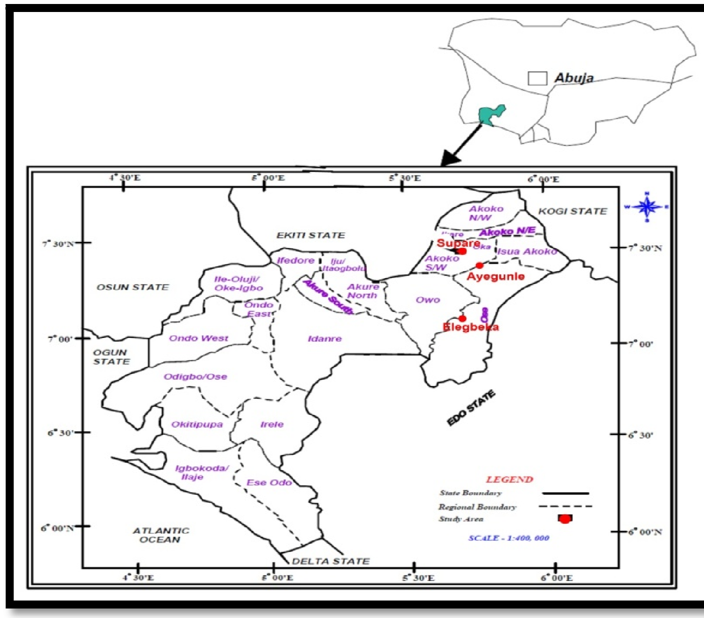



**Fig. 2. Map of Ondo State Showing the Study Area (Source: Oparinde and Ojo, 2014).**

The geological history of the study areas is similar to the structural evolutions that had affected the basement complex of Nigeria. However, according to Rahaman (1976 and 1988a) the area is underlain by Migmatite-gneiss-quartzite Complex rocks with the granite gneiss and grey gneiss being the major unit while the minor units include Mafic, Leucocratic granite, granodiorite, pegmatite, garnet-sillimanite gneiss and quartzite. Some of these rocks are low-lying, hilling, and dike-like in nature. The geologic processes alter the rock units to create geological structures (faults, folds, joints, lineaments and shearing) and variety of lateritic soil being a product of in-situ weathered of the parent rocks. These weathered zones and geologic structures are

pathways for transport of geologic materials and fluids.

## Materials and Methods

The ground magnetic and radiometric investigations were conducted on foot using GSM-19T Proton Precision Magnetometer and portable hand held detector Gamma Ray Spectrometer respectively with Garmin Global Positioning System (GPS) navigational equipment for real-time measurements. A base station was carefully selected and established near the respective quarry site where the magnetometer was been continuously returned to correct for diurnal variations of earth magnetic field and other sources of external origin. Two magnetic and radiometric measurements were taken per station employing a traverse length of 1000m of spacing 5 m each for total traverses of: Elegbeka Quarry (4), Ayegunle Quarry (4) and Supare (3) respectively. A total of 11 readings were taken at the base stations together with readings of the time for the magnetic survey. The mean of the magnetic and radiometric measurements was adopted as the raw data for each observed stations and acquired data was drift corrected. Twenty topsoil samples (Elegbeka quarry (7), Ayegunle quarry (7) and Supare quarry (6)) were collected from the study area at a depth of about 5-10 cm.

Oasis Montaj™ (Grid and Image tool in Geosoft® software) was used for magnetic and radiometric data processing to prepare the dataset and images production for interpretation. The elemental analyses of all the soil samples were carried out using the Energy Dispersive X-ray Fluorescence (EDXRF) spectrometry. The spectrometer brand name is ECLIPSE Ш. The quantitative analysis of samples was carried out using the XRF-FP Quantitative Analysis Software package. It converts elemental peak intensities to elemental concentrations and or film thickness.

The Total Magnetic Intensity (TMI) image for respective quarry employed the use of minimum gridding curvature to prepare the grid and Fast Fourier Transform (FFT) was later used for step-by-step filtering to improve the qualities for better understanding of the subsurface geology. The Average Radially Power spectrum, Euler plots and its 3D for the depth estimates were produced for respective quarry site investigated using the same package, details can be found in Dobrin and Savit (1988).

The results of the K (%), U (ppm) and Th (ppm) with their Coordinates for respective quarry in the study area were imported into Oasis Montaj™ to produce the Ternary images. Micro-levelling the entire data set to remove any apparent residual errors employing mini-curvature gridding. Ternary Red-Green-Blue (RGB) colour models were produced from the software: Potassium, Thorium and Uranium were assigned to the green, red and blue respectively because the blue tends to reduce the poorest signal-to-noise ratio of Uranium channel.

Microsoft Excel was used to produce the profiles K (%), U (ppm), Th (ppm) and the concentration of the major elements, heavy metals and trace elements bar plot respectively for the three quarry sites investigated in the study area for clearer pictorial representation of the level of radiations and chemical concentrations in the study area.

## Results and Discussion

The results of the magnetic and radiometric methods as well as geoenvironmental assessment are presented below as maps (TMI, TDR, HD_TDR, Euler Deconvolution with 3D depth plot and RSPS), profiles for radio-elements, bar plot for geo-environmental assessment and 3D radionuclides emissions images.

## Magnetic Maps and Images

The magnetic data obtained along traverses at respective quarry sites in the study area were used to produce the Total magnetic intensity (TMI) maps to deduce the range of the magnetic intensity of the rocks with the infilled geologic materials, geologic structures and areas that are susceptible. Evaluation of the individual maps revealed amplitude variation between -3326.79nT and 1284.61nT. These values are not uncommon in a basement complex (Telford et al., 1990). The total magnetic intensity varies from one location to the other, due to the mineral content in the surface and subsurface rocks and its structural mapping.

The Total magnetic intensity (TMI) maps for Elegbeka, Ayegunle, and Supare quarries are shown in Fig. 3(a,b,c). The TMI of Elegbeka quarry (Fig. 3a) shows amplitude variation in magnetic intensity between -650.74nT and 114.31nT, Ayegunle quarry (Fig. 3b) shows variation between -3326.79nT and 1284.61nT, and Supare quarry (Fig 3c) shows variation in intensity between -267.70nT and 108.92nT. Areas denoted by A, B, C, and H are areas with the high amplitude of magnetic intensity suggest the presence of the basement rocks occurring at shallow depth below the surface, while the low negative amplitude in magnetic intensity (D, E and G) are areas indicating the zones of weaknesses that suggest the presence of geologic structures (fractures, faults and lineaments).The varying magnetic intensity suggests varying magnetic materials associated with the rock types in the area. According to Gunn et al., 1997a, the amplitude of a magnetic anomaly is directly proportional to magnetization which depends on magnetic susceptibility of the rocks. Faults are delineated on the TMI maps as F-F', J-J', and K-K' with structural trend of NE-SW and some of the faults are perpendicular to the strike direction with infilled geologic materials (E).

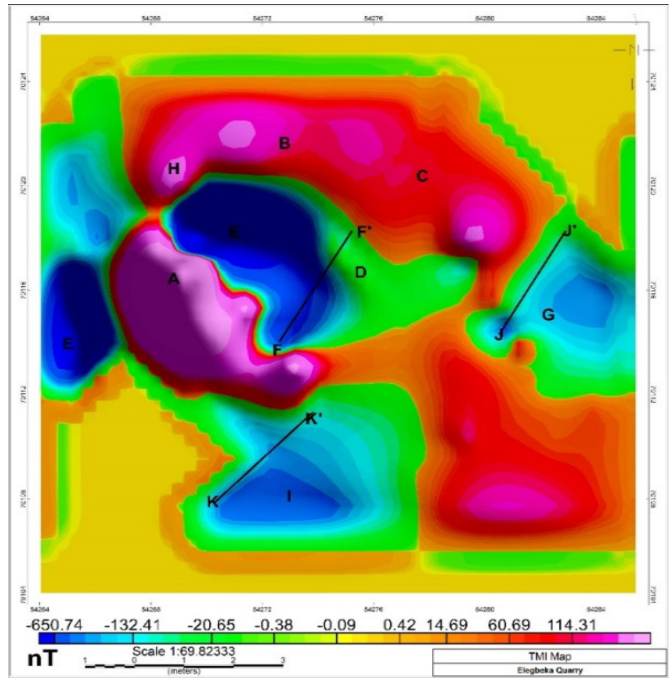



**Fig. 3a. Total Magnetic Intensity (TMI) of the Study Area: (A) Elegbeka Quarry.**

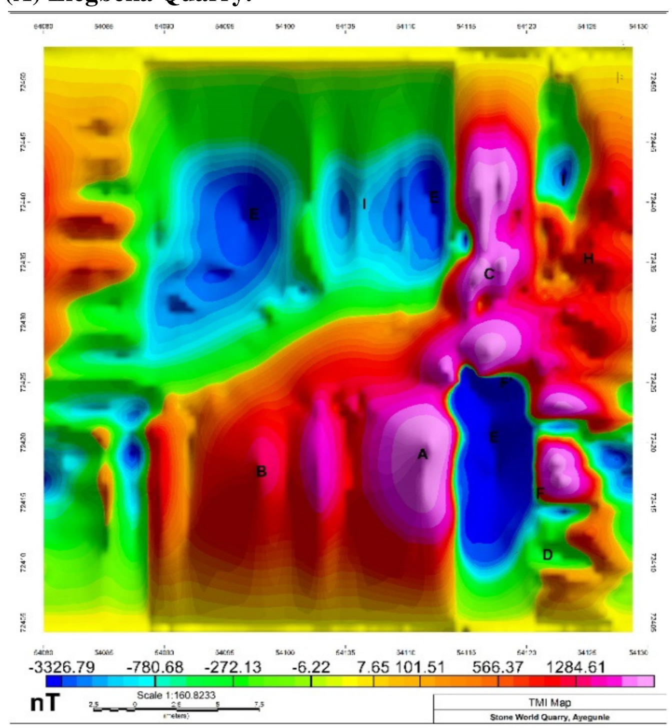



**Fig. 3b. Total Magnetic Intensity (TMI) of the Study Area: (B) Stone World Quarry, Ayegunle.**

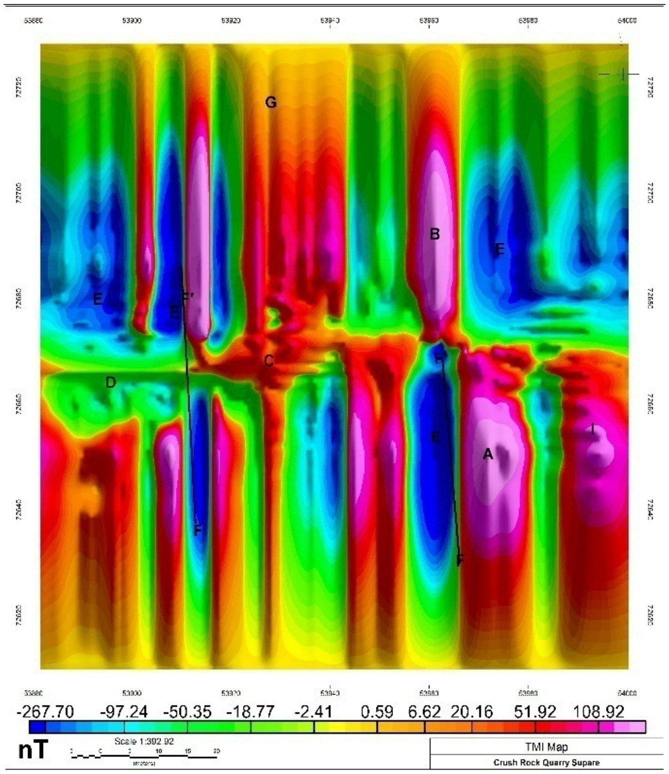



**Fig. 3c. Total Magnetic Intensity (TMI) of the Study Area: (C) Crush Rock Quarry, Supare respectively.**

The Tilt Derivative (TDR) and its Horizontal component (HD_TDR) maps for Elegbeka, Ayegunle, and Supare quarries (Figs. 4 and 5) were derived from the tilt derivative filter applied to the TMI grids to determine structures (fault and folds), the contacts and edges or boundaries of magnetic sources, and to enhance both weak and strong magnetic anomalies of the area placing an anomaly directly over its source. Tilt angle derivative (TDR) of TMI locates the edges of formations, especially at shallow depths by using the theory that the zero contours are the edges of the formation (Salem et al., 2007). It is observed that the zero contours estimate the location of abrupt changes in magnetic susceptibility values. The zero contour lines are represented by yellow colour, areas which show the lineaments are those with blue colour, while those with red are the undeformed or unweathered basement. Figure 4 and 5 displays most structural feature of the area such as the faults, contacts and the shape of some lithology. Figure 4(a,b,c) shows the resolution of the tilt angle derivative (TDR) in the vertical direction while Figure 5(a,b,c) shows the resolution of the tilt angle derivative (TDR) in the horizontal direction of the study area. Comparing Figure 4 and Figure 5 below, the TDR image shows different lineaments and contacts in the area.

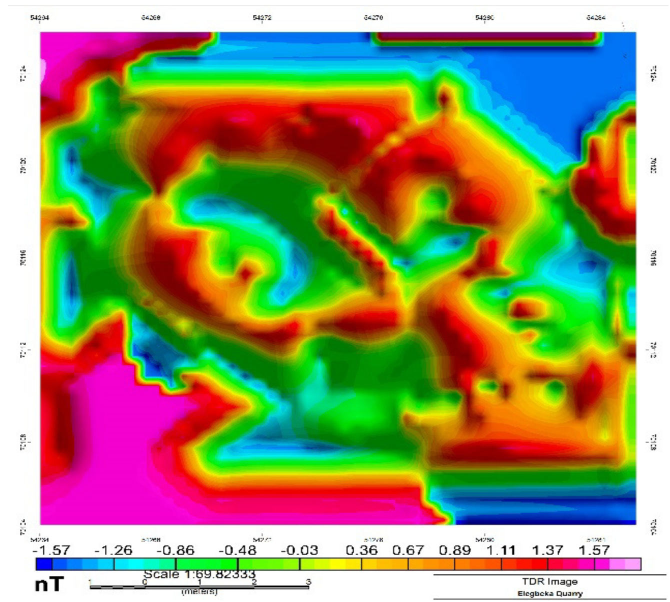



**Fig. 4a. Tilt angle derivative (TDR) derived from TMI of the Study Area: (a) Elegbeka Quarry.**

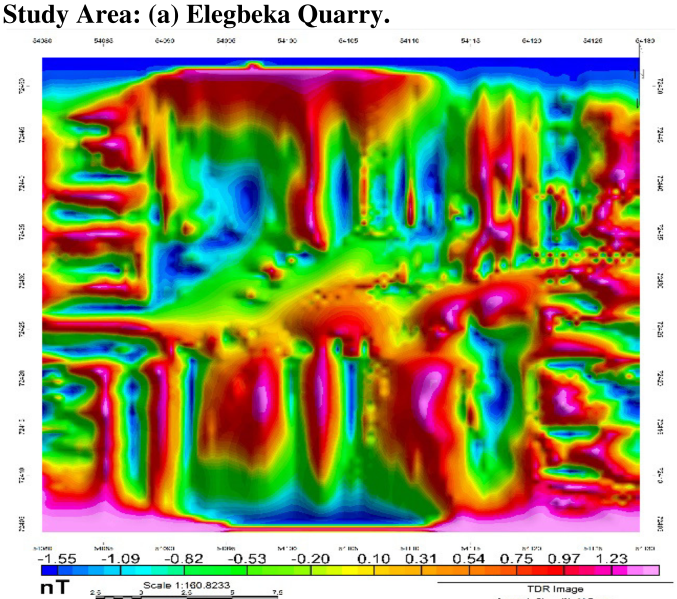



**Fig. 4b. Tilt angle derivative (TDR) derived from TMI of the Study Area: (b) Stone World Quarry.**

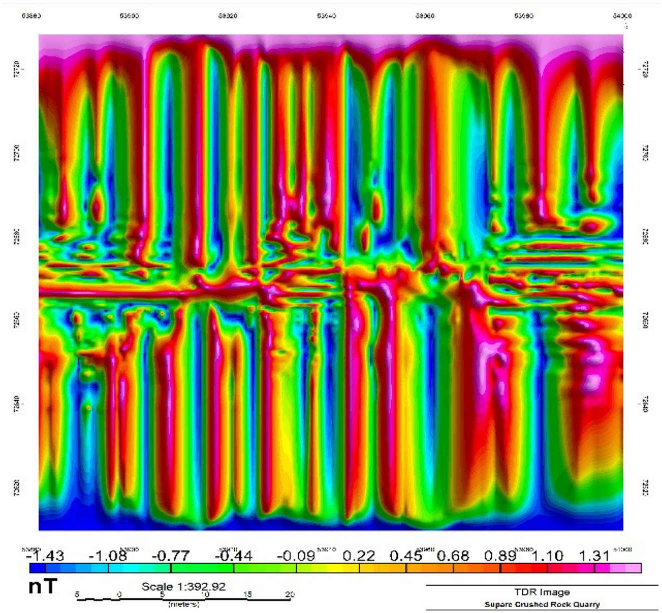



**Fig. 4c. Tilt angle derivative (TDR) derived from TMI of the Study Area: (c) Crush Rock Quarry, Supare.**

The underlying geology of Ayegunle quarry (Figs. 4b & 5b) and Supare Quarry (Fig 4c and 5c) respectively show that the lineament structures with approximate vertical and horizontal trends with break in subtle of these areas are more complex compared to the underlying geology of Elegbeka (Figs. 4a & 5a) that the lineament structures and their shapes are detailed. It could be inferred that Ayegunle and Supare quarrying and mechanical activities have contributed to natural fracturing density of the underlying geology. It is evident that the earlier delineated structural trends on the TMI maps have similar trends of NE-SW, NW-SE and most perpendicular to the strike direction on the TDR and HD_TDR maps.

Fig. 6(a,b,c) shows the Euler Deconvolution maps with its three-dimensional (3D) view of the quarry sites in the study area, used for location and depth determination of causative anomalous bodies from gridded potential field data. The method starts by calculating the analytic signal grid, finds peaks in the grid, then use these peak locations for Euler deconvolution. The depths of respective anomalous sources are determined for each quarry site. The zones of weakness (weathered, fractures, faults, lineaments and infilled geologic materials) are areas with the low values (blue) suggesting deeper depth, while areas with high values (red-pink) are basement rocks enclosing the structures with the infilled materials and these suggest that are shallow depth. Elegbeka quarry (Fig. 6a) shows fewer geologic structures with lesser infilled geologic materials compared to the two other quarries (Fig. 6b & 6c). The orientations of the structures with their depths are evident of the robustness of this enhanced method for location and depth determination of causative anomalous bodies pictured well on the Euler 3D view, sequentially revealing the anomalous zones at the base of the basement close to the surface with some outcropping at the surface.

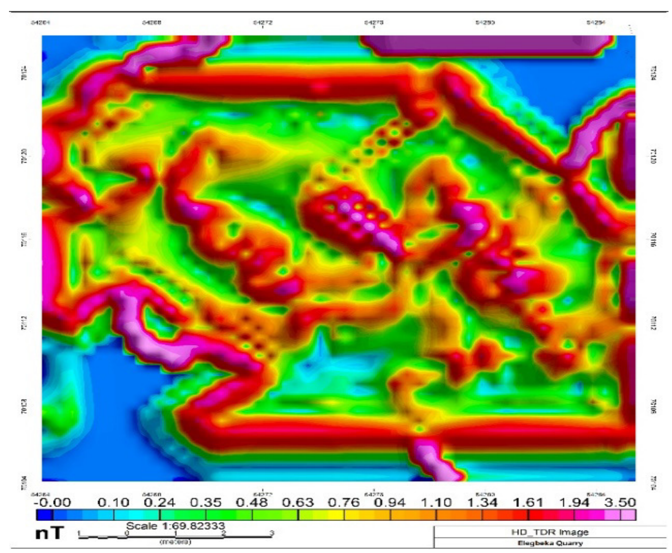



**Fig. 5a. Tilt angle derivative (HD_TDR) in the horizontal direction derived from TMI of the Study Area: (a) Elegbeka Quarry.**

The Radial Average Power Spectrum (RAPS) (Fig. 7) of the study area shows the total estimate depths to the top of geologic sources that produced the observed anomalies in the magnetic map and were determined using spectral analysis. Elegbeka quarry (Fig. 7a), the depths to the magnetic sources ranges from 200m to 700m, Ayegunle quarry (Fig. 7b) range

from 100m to 800m and Supare quarry (Fig. 7c) ranges from 5m to 760m in the study area. The depths of the anomalous bodies in Supare quarry (Fig. 7c) showed that the anomalous bodies are very close to the surface because the depth estimations from the power spectrum and that of Euler are indicating near surface of the bodies compared to other two quarries. But the beauty of their depths is that they all have the same close deep depth extents.

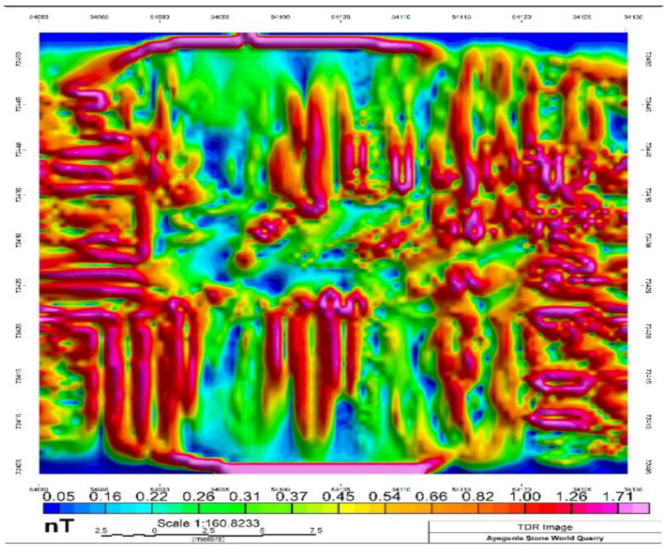



**Fig. 5b. Tilt angle derivative (HD_TDR) in the horizontal direction derived from TMI of the Study Area: (b) Stone World Quarry.**

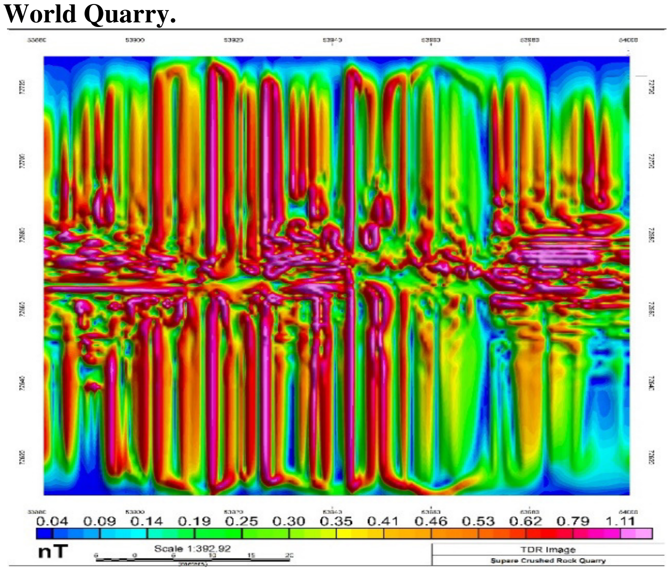



**Fig. 5c. Tilt angle derivative (HD_TDR) in the horizontal direction derived from TMI of the Study Area: (c) Crush Rock Quarry, Supare.**

## Radiometric Profiles and Maps

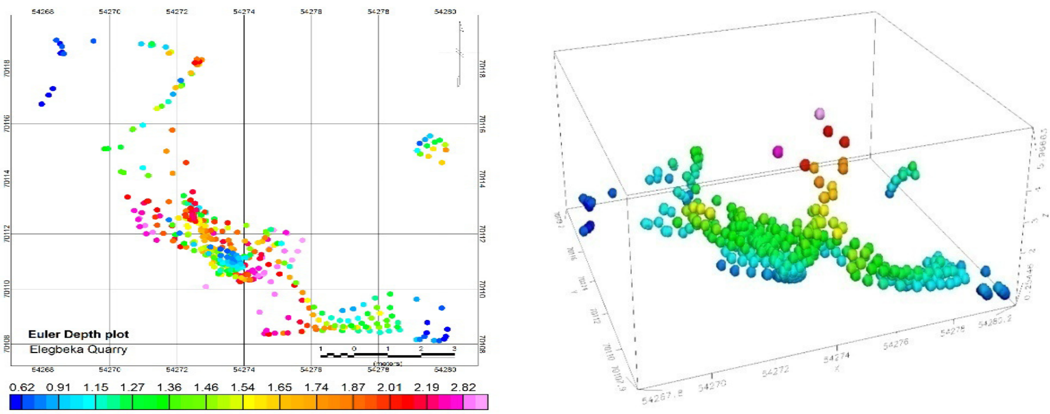
The radiometric profiles were produced to establish evidences from the geologic formations about the radiation level of the three quarries investigated in the study area. Besides, to ascertain if this method is a good mapping tools in relation to magnetic method earlier interpreted.

The $^{40}K$ (%) level of Elegbeka, Ayegule and Supare quarries are with mean of 3.14 %, 2.56 % and 2.86 % respectively. Elegbeka quarry has the highest concentration level of $^{40}K$ suggesting that the geologic formation of the area is richer in potassic feldspar and this also show less weathering rate of the parent rocks compared to the two other quarries. On the contrast, two possible events must have lowered the $^{40}K$ level of the Ayegunle and Supare quarries which are: intensive weathering of the feldspar-bearing-minerals in parent rocks into clay particles which must have been eroded from their source and low enrichment of the parent rocks in potassic feldspar in relation to other feldspar minerals.

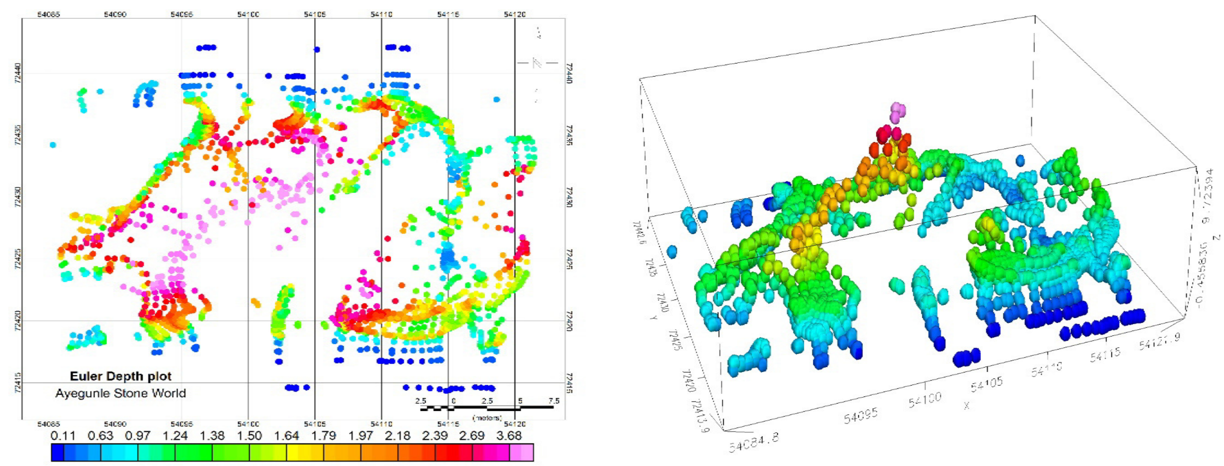
The $^{238}U$ (ppm) level of Elegbeka, Ayegule and Supare quarries are with mean of 8.4 ppm, 3.6 ppm and 4.8 ppm respectively. While, the $^{232}Th$ (ppm) level of Elegbeka, Ayegule and Supare quarries are with mean of 25.7 ppm, 11.9 ppm and 11.3 ppm respectively. The same increase in the level of $^{238}U$ and $^{232}Th$ in Elegbeka quarry have proved the aforementioned two events that had actually happened in the other two quarries that resulted to almost the same values of U and Th respectively, but the U concentration level of Ayegunle is slightly higher than Supare quarry site. Consequently, the Uranium-bearing-minerals (Uraninite, Urathorite

**(a)**




**(b)**




**(c)**

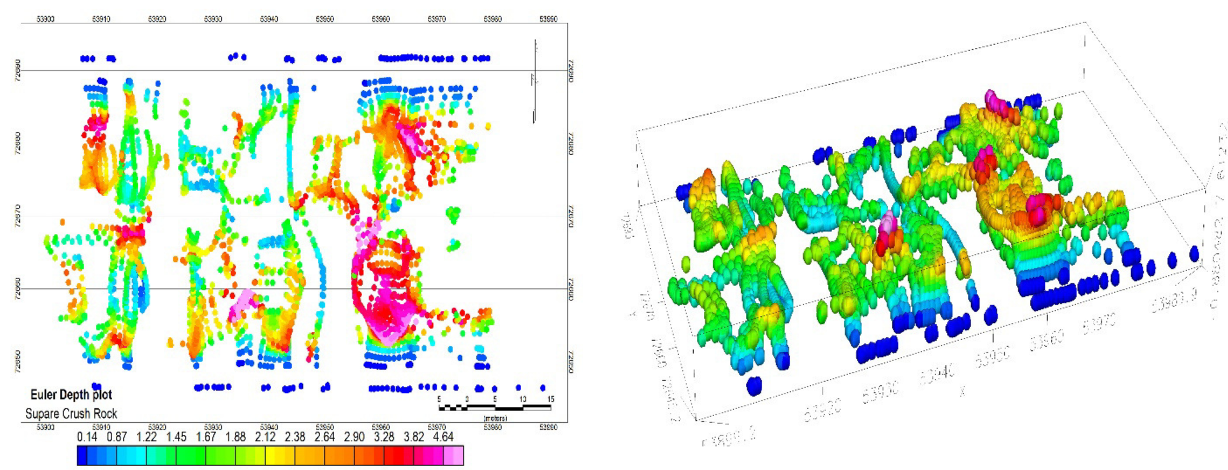



**Fig. 6. Euler Deconvolution and its 3D view for depth estimation of the anomalous zones. (a) Elegbeka Quarry; (b) Stone World Quarry, Ayegunle and (c) Crush Rock Quarry, Supare respectively.**

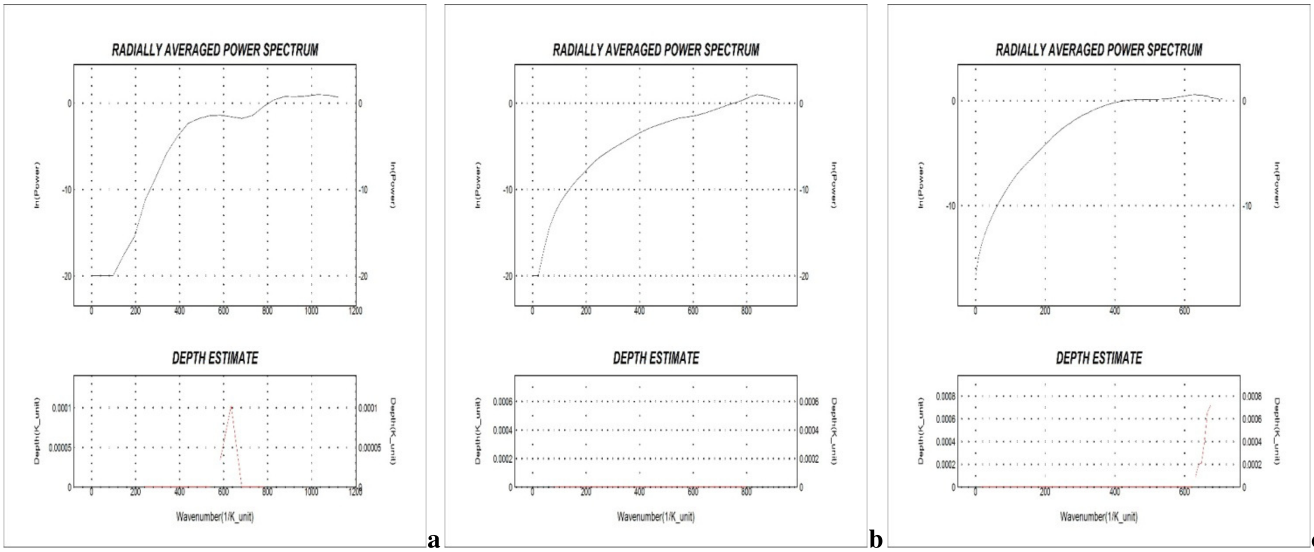



**Fig. 7. Radially Averaged Power Spectrum and Depth Estimate (RAPS). (a) Elegbeka Quarry; (b) Stone World Quarry, Ayegunle and (c) Crush Rock Quarry, Supare respectively.**

etc.) have been weathered because of their susceptibleness to weathering compared to Thorium-bearing-minerals (Monazite, Zircon etc.) that are resistance to weathering. The robustness of Th-rich geologic formation is evident in Elegbeka quarry site with the highest mean value. This increase suggests that the richness in Th could have resulted from the terrestrial gamma radiation, less weathering and low fracturing density of the parent rocks that would have accumulated materials that are non-radioactive.

This method has shown its worthiness and robustness as a good geophysical mapping tool because it has been able to characterize the radioelements and susceptibilities of the rocks; that the surface and subsurface lithological influence and distribution of the acidic rocks like granite are radioactive and basic and ultrabasic rocks in the studya area area relatively more magnetic and vice visa. The natural environmental radioactivity in a location depends primarily on its geological and geographical conditions. It is related to the composition of each lithologically separated area and the content of the rock from which the soil originates (Whicker, 1983; Wollenberg and Smith, 1990).

## Geochemical Survey

Table 1 shows the concentration of respective major elements, heavy metals and trace elements of the soil samples taken from different points in the study area. The effects of quarrying activities could pose to life in the communities when they are engaged in agricultural activities on which the soil, surface and groundwater have been invaded by contaminants. This test was carried out because of the nature of the activities engaged in: such as blasting of rocks with explosives and with use of different machineries for coring, transporting quarried and processed materials. These explosives and machineries are made from both heavy chemicals and metals that are poisonous if the remnants are inhaled from explosive dust after blasting or leftover in soil from corroded worn and abandoned machines.

The quarrying activities have actually affected the fracturing system of the rocks in study area creating in them post-secondary fracturing and jointing systems that could serve as passage way for migration of both soluble and insoluble contaminated water and soil if such are present.

Table 1. Concentration of heavy metals and trace elements in soil samples collected from the Quarries in the study area.

| Location | K (%) | Ca (%) | Ti (%) | Cr (ppm) | Mn (ppm) | Fe (%) | Cu (ppm) | Zn (ppm) | Mo (ppm) | As (ppm) | Ce (ppm) | Zr (ppm) | Pb (ppm) | V (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elegbeka | 2.58 | 1.18 | 4.7 | 4.33 | 92.5 | 39.0 | 11.8 | 23.1 | 56.0 | 1.2 | 15.0 | 7.5 | 15.1 | 39 |
| Ayegunle | 1.8 | 1.2 | 4.3 | 6.5 | 112 | 42.8 | 42.6 | 32.1 | 170 | 1.7 | 23.3 | 11.5 | 27 | 3.7 |
| Supare | 2.4 | 3.0 | 3.7 | 4.3 | 65.0 | 35.8 | 31.0 | 35.0 | 9.0 | 7.0 | 7.6 | 92.0 | 39.0 | 43.0 |
| Mean | 2.26 | 1.79 | 4.23 | 5.04 | 89.83 | 39.2 | 28.47 | 30.07 | 78.33 | 3.30 | 15.30 | 37.0 | 27.03 | 28.57 |
| Tolerance Level | ND | ND | ND | 100 | ND | ND | 50 | 300 | ND | 20 | ND | ND | 100 | 87 |
| UCCA | 2.8 | 3.59 | ND | 92 | 650 | 5.04 | ND | 67 | ND | ND | 63 | 193 | ND | 97 |

The major elements that constituted the host rocks such as K, Ca, Ti, and Fe have mean 2.26 %, 1.79 %, 4.23 % and 39.2 % respectively. The heavy metals: Cu, Zn, As, and Pb have mean 28.7 ppm, 30.07 ppm, 3.30 ppm, and 27.03 ppm respectively. Also, the trace elements in soil samples: Cr, Mn, Mo, Ce, Zr, and V have mean of 5.04 ppm, 65.0 ppm, 78.33 ppm, 15.30 ppm, 37.0 ppm, and 28.57 ppm respectively.

The concentration of potassium (K) in the soil samples collected from the study area (three quarry sites) vary from 1.8 % to 2.58 % (Table 1) respectively with the maximum concentration at Elegbeka, suggesting that Elegbeka quarry is enriched in potassic feldspar compared to the other two quarries. The concentration of calcium (Ca) in the soil samples varied from 1.18 % to 3.0 % (Table 1) respectively. Supare quarry site has the maximum concentration suggesting that the parent rocks are rich in calcium carbonate ($CaCO_3$) compared to the other two quarries. The concentration of titanium (Ti) from the quarries also varied from 3.7 % to 4.7 % (Table 1). Therefore, all samples are not elevated compared to the upper continental crust abundance (UCCA) value of 2.8 % for potassium and 3.59 % for calcium respectively, except for titanium UCCA that cannot be determined. The concentration of iron (Fe) in the soil samples collected from the quarry sites varies from 35.8 % to 42.8 % (Table 1) respectively and values are above the upper continental crust abundance (UCCA) value of 5.04 %.

The concentration of copper (Cu) in the analyzed soil samples within the quarry sites ranged from 11.8 ppm to 42.6 ppm with the maximum concentration at Ayegunle quarry (Table 1) respectively. The values are below the NIER (2007) tolerance level of 50 ppm as permissible standard.

The concentration of zinc (Zn) in the soil samples varied from 23.1 ppm to 35.0 ppm with the maximum concentration at Supare quarry (Table 1) respectively. The values are below the NIER (2007) tolerance level of 300 ppm and were not elevated above the upper continental crust abundance (UCCA) value of 67 ppm.

The concentration of arsenic (As) in the soil samples from the study area varied from 1.2 ppm to 7.0 ppm with maximum concentration at Supare (Table 1). The approximate mean concentration of arsenic in the soil samples is 3.3 ppm but when compared with the standard is below NIER (2007) tolerance value of 20 ppm for heavy metals.

The concentration of lead (Pb) in the soil samples collected from the study area varies between 15.1 ppm and 39.0 ppm with the maximum concentration at Supare quarry (Table 1). All values of lead concentration obtained in the study area are below NIER (2007) tolerance level of 100ppm.

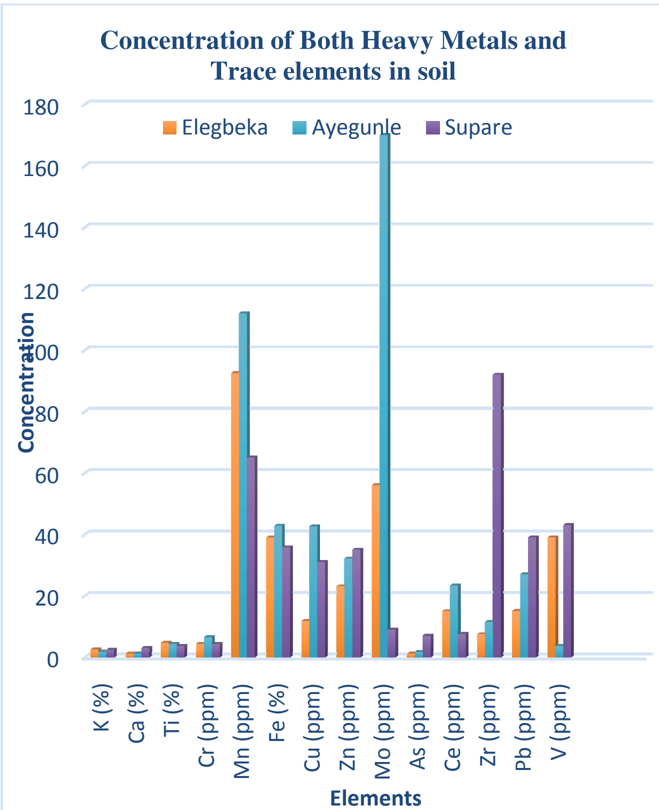



**Fig. 8. Bar plots for concentration of both heavy metals and trace elements in soil samples in the study area, indicating the high level of Mo, Mn and Zr amongst other elements measured in ppm, while Fe takes the lead amongst the major elements that constitute the framework of every rock. Ayegunle and Supare quarry sites within the study area envisaged more enrichment of some these elements compared to Elegbeka.**

The concentration of trace elements such as Cr, Mn, Mo, Ce, Zr, and V (Table 1) are below the upper continental crust abundance (UCCA) and NIER (2007) tolerance level respectively in the study area. Molybdenum (Mo) has the highest concentration of all the trace elements in the soil samples collected from the study area.

From Table 1, the abundance of the major elements are in the order of Fe>Ti>K>Ca, heavy metals: Zn>Cu>Pb>As and trace elements: Mo>Mn>Zr>V>Ce>Cr respectively in the soil samples collected from three quarry sites in the study area.

Figure 8 shows the bar plot for all the elements for better pictorial clarification. This pictorial view gives a better explanation and to the increasing and decrease orders of the major elements, heavy metals and trace elements explained above using Table 1. From the bar plot, deduction indicates that Ayegunle and Supare quarry sites within the study area have more concentration of all these elements than Elegbeka, suggesting that intensive quarry activities have contributed to the abundance of these elements.

## Conclusion

The study have shown the worthiness and the importance of magnetics and radiometric methods in effective mapping out of lithologies, characterizing magnetic intensities and radionuclides, delineating subsurface structures¸ anomalous zones with depth to magnetic sources, and the robustness of X-Ray fluorescence (XRF) in determining the geoenvironmental hazard potential of concentrations of major elements, heavy metals and trace elements present in soil.

Inspection of the individual Total magnetic intensity (TMI) maps revealed the range of the magnetic intensity of the rocks with the infilled geologic materials, geologic structures and areas that are susceptible of intensity with amplitude variation between -3326.79 nT and 1284.61 nT. The tilt derivative (TDR) with the horizontal component (HD_TDR) showed that the lineament structures to be trending approximately in slant, vertical and horizontal directions with break in subtle (as shape of the structures), but Elegbeka revealed detailed underlying geology compared to other quarry site. It

is evident that the TMI maps have similar trends of NE-SW, NW-SE and some perpendicular to the strike direction with those on the TDR and HD_TDR maps.

3D Euler deconvolution and RAPS images showed different range of depth estimates between 100m to 800m indicating the total depth estimate to the top of geologic sources that produced the observed anomalies. The varying magnetic intensity suggests varying magnetic materials associated with the rock types in the area.

The radiometric profiles established evidences from the geologic formations about the radiation levels of the three quarries investigated in the study area The $^{40}$K (%) radiation level of Elegbeka, Ayegule and Supare quarries have mean of 3.14 %, 2.56 % and 2.86 % respectively. The $^{238}$U (ppm) level were with mean of 8.4 ppm, 3.6 ppm and 4.8 ppm respectively. While, the $^{232}$Th (ppm) level for Elegbeka, Ayegule and Supare quarries have mean of 25.7 ppm, 11.9 ppm and 11.3 ppm respectively. Geologic events like intensive weathering of the feldspar-bearing-minerals in parent rocks into clay particles have been eroded from their source and low enrichment of the parent rocks in potassic feldspar in relation to other feldspar minerals must have caused the radioactivity level K, U and Th in Ayegunle and Supare quarries.

Elegbeka quarry has the highest radiation level of $^{40}$K, $^{238}$U and $^{232}$Th, suggesting that the geologic formation of the area is richer in potassium-bearing-minerals, Uranium-bearing-minerals and Thorium-bearing-minerals respectively. Weathering rate of the parent rocks, terrestrial gamma radiation enrichment in parent rocks, and low fracturing density system of the parent rocks that would have accumulated materials that are non-radioactive could all have accounted for the radioactivity level of Elegbeka compared to the two other quarries. It could be inferred from the following that Ayegunle and Supare quarrying and mechanical activities have contributed to natural fracturing density of the underlying geology.

The Ternary images on the other hand showed the contributions from the 3 radioelements K, U and Th distinctively based on the concentration of each and were able to show that Th has the highest area distribution in relation to K and U. Ternary image for Elegbeka revealed great level of disparity from the other two images.

The abundance of the major elements to be in the order of Fe>Ti>K>Ca, heavy metals: Zn>Cu>Pb>As, and trace elements: Mo>Mn>Zr>V>Ce>Cr respectively in the soil samples collected from three quarry sites in the study area. All metals and elements were below the upper continental crust abundance (UCCA) and NIER tolerance level respectively with exception of iron (Fe) that was above the upper continental crust abundance (UCCA). The increase in level of iron concentration above the upper continental crust abundance (UCCA) suggests that the area is enriched in such in element above the initial crust abundance in the parent rocks indicating the effect which quarrying/mining activities have on the environment. Hence, the enrichment of the study area in iron provides evidence about that the parent rocks to be very rich in ferromagnesian minerals.

This study reveals that the quarrying activities in the study area have affected the geologic formation causing more fracturing in rocks and pronounced subsurface structures as a result of blasting and crushing that could serve as passage for leachates from pollutants as well as the level of radiation in the study area. Chemical concentration form explosives and machineries thereby increasing the level of chemical concentrations and elements in the soil, which in later years could lead to poisonous concentrates in soil, surface water and groundwater.

The study found that the analyzed soil samples from the study area when compared with international standard have shown that the area is safe to humans for agricultural practices, drinking, mining and domestic purposes.

**References**

Adabanija, M. A. and Oladunjoye, M. A. 2014. Geoenvironmental assessment of abandoned mines and quarries in South-western Nigeria. Journal of Geochemical Exploration, 145, 148–168.

Dobrin, M.B., and Savit, C.H. 1988. Introduction to Geophysical Prospecting. New York, McGraw-Hill, pp.867.

Esshaimi, M., Quazzani, N., Avila, M., Perez, G., Valiente, M. and Mandi, L. 2012. Heavy metal contamination of soils and water resources Kettara abandoned mine. Am. J. Environ. Sci., 8(3), 253-261.

Folami S.L. 1992. Interpretation of Aero magnetic Anomalies in Iwaraja area, Southwestern Nigeria. Journal of Mining and Geology, 28(2), 391–396.

Gregory, A. and Horwood, J. 1961. A laboratory study of gamma-ray spectra at the surface of rocks. Ottowa Department of Energy, Mines and Resources.

Gunn, P., Maidment, D. and Milligan, P. 1997a. Interpreting aeromagnetic data in areas of limited outcrop. AGSO Journal of Australian Geology & Geophysics, 17(2), 175–185.

Jarup, L. 2003. Hazards of heavy metal contamination. Brit. Med. Bull., 68, 167-182.

Kachenko, A.G. and Singh, B. 2006. Heavy metal contamination in vegetables grown in urban and metal smelter contaminated sites in Australia. Water Air and Soil Pollut., 169, 101-123.

Nettleton, L.L. 1976. Gravity and Magnetics in oil prospecting. McGraw- Hill, New York, pp. 394-413.

NIER, 2007. Investigation of the impact of mine discharge on Han-river watershed. 1st year's report. pp. 35-47.

Obaje, N.G., Wehner, H., Scheeder, G., Abubakar, M.B., and Jauro, A. 2004. Hydrocarbon prospectivity of Nigeria's inland basins: from the viewpoint of organic geochemistry and organic petrology. AAPG Bulletin, 87, 325-353.

Oliver, M. A. 1997. Soil and human health: a review. European Journal of Soil Science, 48, 573–592.

Oparinde, L.O. and Ojo, O. O. 2014. Structural performance of artisanal fish marketing in Ondo State, Nigeria. American Journal of Rural Development, 2(1), 1 – 7.

Oyawoye, M.O. 1972. The Basement complex of Nigeria. In: Dessauvagie TFJ and Whiteman AJ (Ed.) African Geology, University of Ibadan pp 66-102.

Rahaman, M. A. 1988 a. Recent advances in the study of the basement complex of Nigeria. In: P. O. Oluyide (Co-ordinator), Precambrian Geology of Nigeria. Geol. Surv. Nigeria. Publ., pp. 11-43.

Rahaman, M.A. 1976. A review of the Basement Geology of Southwestern Nigeria. Kogbe, C.A. (ed.), Geology of Nigeria, Elizabeth Publishing Co., pp. 41 – 58.

Rudnick, R.L. and Gao, S. 2003. Composition of the continental crust. In: Holland, H.D., Turekian, K.K., Rudnick, R.L. (Eds.), The Crust. Treatise on Geochemistry, 3. Elsevier-Pergamon, Oxford, pp.1–64.

Salem, A., Williams, S., Fairhead, J., Ravat, D. and Smith, R. 2007. Tilt-depth method: a simple depth

estimation method using first-order magnetic derivatives. The Leading Edge, 26, 1502-1505.

Taskin H., Karavus M., Topuzoglu A., Hindiroglu S. and Karahan G. 2009. Radionuclide concentrations in soil and lifetime cancer risk due to the gamma radioactivity in Kirklareli, Turkey. Journal of Environmental Radioactivity, 100, 49-53.

Telford, W.M., Geldart, L.P. and Sheriff, R.E. 1990. Applied Geophysics (Second edition). Cambridge University Press.

UNSCEAR. 2000. United Nations Scientific Committee on Effect of Atomic Radiation. Report to the general assembly Annex B: Exposure from natural radiation source.

Whicker, F.W. 1983. Radionuclide transport processes in terrestrial ecosystems. Radiation Research, 94, 135-150.

Wollenberg, H.A. and Smith, R.A. 1990. A geochemical assessment of terrestrial gamma-ray absorbed dose rates. Health Physics, 58, 183-189.

**Cite this article:** Okpoli, C.C. and Akingboye, A.S. 2016. Magnetic, Radiometric and Geochemical Survey of Quarry Sites in Ondo State, Southwestern, Nigeria. International Basic and Applied Research Journal, Volume 2, Issue no. 8, pp. 16-30.